DOCUMENT RESUME

ED 298 898 IR 013 283

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TITLE Human Information Processing.
PUB DATE 84
NOTE 16p.; In: Instructional Development: The State of the Art, II; see IR 013 273. For volume I, see ED 292 444.
PUB TYPE Information Analyses (070) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; Educational Technology; Information Transfer; *Instructional Development; *Memory; Models; Perception; Psychological Studies; *Schemata (Cognition)
IDENTIFIERS *Perception Research

ABSTRACT

Focusing on the psychological processing of audiovisual materials by learners, this chapter presents and analyzes recent research on human perception, its relation to memory, and how perception is best represented in an information processing model. Topics discussed include pictorial and verbal memory, information system capacity, filtering and pigeonholing, information reduction, system overload, organizational schemata, and multimodal perception. Also considered are simultaneous and sequential information processing, transfer of information across perceptual systems, and the emerging view of the human as an information processing system. Reasons for the study of perception by instructional developers are suggested, and an argument is made for the expansion of the scientific basis of educational technology through perception research. (15 references) (Author/EW)

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A. BASIS OF DESIGN IN THEORY

Chapter 10

Human Information Processing

Robert M.W. Travers

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Instructional developers typically produce audiovisual materials, or at least design them. When IDers don't do this they often specify their use within instructional sequences. Therefore IDers need to understand how learners process these materials as they learn, or fail to learn, from them. This chapter examines what we know about this process.

SCOPE AND LIMITATIONS OF THE CHAPTER

The last few decades have seen the production of a vast literature on human information processing that can be summarized here in only the sketchiest fashion. Contributions to this area come from neurophysiology, computer science, cognitive psychology, epistemology, mathematical information theory, electronic modeling, genetics, and other branches of knowledge. The sketch of human information processing provided here draws upon many sources, some of which are listed in the final section on "Sources." The broad scope of the chapter does not permit detailed documentation; the reader who wishes to pursue the subject further is referred to works which give broad coverage and, in turn, will provide references at a still more detailed level.

The limited length of the chapter restricts coverage not only to rather broad generalizations, but also has required the omission of certain topics. The very significant research on memory of the past 15 years has been largely ignored. Information processing, though always related to memory, is viewed largely as an intake process with little consideration of how memory and memorized information is structured.

APPROACHES TO THE STUDY OF HUMAN BEHAVIOR

Human behavior can be viewed in many different ways by scientists with different backgrounds. Those who come to psychology with a background in physiology and biology are likely to be impressed with the physical similarity between the human organism and organisms rather lower on the evolutionary scale. These psychologists have typically taken the position that human behavior is similar to animal behavior. Such a theory generally implies that human behavior involves the same basic components as animal behavior. Those who have approached behavior with such a viewpoint during the last half century have typically taken the view that the basic components of behavior involve some form of conditioned response. Complex behaviors are then assumed to be chains of conditioned responses. Conditioning theory has emerged in many forms during the last 100 years. Its main proponents at the present time are followers of Pavlov and Luria in Russia and the followers of Skinner in the United States. The modern version of conditioning theory conforms very closely to the associationistic theory of Western civilization.

Another way of viewing human behavior is to

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see it as a rational, logical system. This viewpoint has slowly emerged into a position of prominence in recent years through the work of Jean Piaget and his followers. It is a revival of the classical Greek view of human nature, and derives its modern support from the fact that many of the great achievements of humanity seem to be linked to the human capacity for logical thought and the understanding of such logical relations as those of implication.

A whole volume could be devoted to a discussion of the various ways in which human behavior can be productively viewed, but the examples given thus far are sufficient to show that there are diverse productive ways. Our own era on the American Continent has generated its own special way of looking at human behavior, and that is to view the human as an information-processing system. This view seems to reflect the trend in thought appropriate to a computer age, in which much of society is controlled by the information systems provided by computers. These devices are, in a sense, extensions of the human intellect, performing very effectively many activities that humans already do rather well. The computer, designed in the image of the human intellect, has thus become, for some, a model and representation of that intellect, and has provided an image of how the human intellect functions. The human is, of course, much more than an information-processing system, just as the human is also much more than a collection of conditioned responses, or a conglomerate of logically-related behavior. Each way of looking at the human has limitations, but each way may still have utility. In this chapter, an attempt will be made to explore the view of the human as an information-processing system and to draw together some of the implications of knowledge in this field.

PERCEPTION AS INFORMATION PROCESSING

For more than a century psychologists have had an interest in one particular aspect of information processing, called perception. This area of inquiry has involved studies of how the sense organs receive information and the nature of the experiences that accompany stimulation of the sense organs. Classical perception theory, developed in the earlier part of the century, took the position that perception was an inactive process. This inactive view was partly a result of a failure to recognize that memory necessarily plays a crucial role in perception, and also a failure to note that perceptual activities involve a great amount of activity on the part of the entire organism. All creatures that have the capability of movement are active explorers of their environment and actively reach out into their environment. The organism is not a passive creature waiting for perception to leave impressions upon its memory systems, but engages in a continuous search of the environment for that which is relevant to survival.

The transition to the view of perception as an active searching process came largely through the work of J. J. Gibson, who recognized that each sensory system has coupled with it a musculature that permitted the system to play far more than a passive role. Thus the eyes not only have built into them sets of muscles which will turn them through at least 90° in each of two planes, but movements of the head can also redirect the direction of gaze. Furthermore, the infant's eyes are not passively fixed until an object attracts the infant's attention, but the eyes scan the environment in a searching type of motion that continues until the infant finds a light or a boundary that attracts attention. The eyes of the infant, from the first few days after birth, search for sources of information that can be assimilated.

Gibson wrote of perception as organized around five different systems. These he referred to as the visual, auditory, taste-smell, haptic, and orienting systems. The haptic system involved both the touch and related systems in the skin and also the sensory systems deep in the muscles that permit the individual to know the positions of the various parts of the body. The orienting system is that associated with the inner ear and which has to do with body balance and the keeping of the body upright in the gravity field.

Traditional forms of instruction violated the way in which the perceptual systems operate. Often a class of children were required to sit upright and keep their eyes fixed upon a teacher seated at a desk. The children were expected to inhibit the natural roving of the eyes that are native to the human visual perceptual system. Indeed, perceptual exploration of any kind was forbidden. Classes run along such lines are still seen today and, in fact, there are some such programs of instruction that are marketed at the lower elementary grades. These programs treat the human perceptual systems as though they were static and simply waiting for knowledge to be poured into vacant minds from the mouth of an all-wise teacher. The native perceptual mechanisms do not fit teacher-centered theories of instruction very well. Such theories deny the learner the opportunity to acquire knowledge through the mechanisms that have evolved for this purpose.

The objection raised here to the eyes-front, regimented type of instructional program should not be taken to imply that learning should occur without discipline. Learning through active exploration through perceptual systems has to become progressively more disciplined as age advances, but it is not the eyes-front, sit-still kind of discipline that is of value. What is needed is the discipline which involves progressively more systematic, active, exploration of objects and events of interest, that progressively becomes guided by logic. The ultimate development of this systematic and disciplined exploration is found in the work of the scientist.

THE MEMORY-PERCEPTION INFORMATION-PROCESSING MODEL

The psychology of the early part of the century viewed perception and memory as quite distinct functions. The distinction comes from philosophers, particularly of the British Empiricist School, who did not understand the vital relationship between perception and memory. In order to understand this relationship, let us consider a mechanical or electronic device that is designed to recognize simple geometrical forms and to tell us what they are.

Let us suppose that this device consists of a perceptual system that scans whatever is in front of it and that it has some kind of memory system. Let us suppose that the outline of a square is placed in front of the device. The machine now has to tell us what it sees. In order for it to do this, the machine must have some information stored in memory that will enable it to make the decision. A machine that had no storage of information, and merely recorded on a photographic plate what it "saw", could never tell us what is was seeing; but our device is designed so that what it perceives influences what it does, just as the action of the human is related to what the human does.

The memory of our device could be built in a number of ways. It could have recorded in its memory geometrical shapes of various forms and sizes, and the input could be matched with what was stored. If the best match was with a square, then the device would tell us that it was viewing a square. Other forms of storage would also permit the device to tell us what it was viewing. The memory might be designed so that it recorded the attributes of geometrical figures, such as straight lines, curved lines, angles, and the number of each kind of components. With such a memory, the device might tell us that any 4-sided figure was a square, much as a 4-year-old child might well do. For the device to do better than that, it would have to be able to use information either about the equality of the internal angles, or the equality of the sides of the figures, or some other equivalent relation.

The point to note is that information is meaningful and useable only in so far as the related memory system has stored in it some information that makes the interpretation of the inputs possible. Also, the system has to have mechanisms which permit the analysis of the inputs in ways that the memory can understand. Thus, if our device had a memory that permitted it to recognize geometrical figures in terms of the properties of their component lines, the device would also have to have a perceptual system that analyzed the information presented to it in terms of lines and their components. The analysis mechanism of the perceptual system has to be compatible with the memory system.

The discussion to this point is not fantasy, for much has been learned about human information processing through attempts to develop tasks that will perform human-like acts. These tasks show, very clearly, the intimate relationship between perception and memory, and the compatibility that must exist between the information-analyzer mechanisms and what is stored in memory. An infant, in the first weeks of life, who gazes at a dark line on the ceiling and shows, through the movement of its eyes, that the line is being scanned from end to end, is also showing that it has a perceptual mechanism that permits it to discriminate lines from other visual displays, and that it has some memory mechanism which permits it to see lines in some way as meaningful objects. Without such inherent mechanisms in both perception and memory, the infant could not even begin to learn about its complex environment. The mechanisms that are built into the nervous system permit the very young infant to begin exploring very simple aspects of a complex world.

Computers have been built to be extensions of the human intellect. They have been designed to undertake some of the kinds of tasks that humans do rather well, but they can perform many of those tasks with vastly greater speed and accuracy than can humans. Computers can be viewed as simulations of the human intellect. Such attempts to simulate the human intellect provide a means for exploring the nature of human intelligence. The computer is very much like a very large piece of paper on which one can draw what one believes to be the essence of human thought and human information processing and storage, but unlike a drawing on a piece of paper, the computer allows one to find out whether the computer, designed in the image of the human, can behave in human-like ways.

These activities related to the computer have generated an enormous amount of interest in the human as an information-processing system. The view of the human as an information-processing system fits well the intellectual interests of our age.

THE EMERGING VIEW OF THE HUMAN AS AN INFORMATION-PROCESSING SYSTEM

The traditional view of the human perceptual system and of the memory system was that it began, at birth, like a blank slate upon which nothing had, as yet, been written. This was the "tabula rasa" of John Locke, for whom knowledge was imprinted on the mind much as an image is imprinted on a photographic film. From that point of view, perception and memory were passive processes. A passive memory recorded whatever the perceptual system happened to transmit to memory. This viewpoint implies that the memory system of the brain is not in any way pre-wired, but that the recording of information in memory slowly establishes a wiring system, through which the information is retained.

There are many difficulties with this representation of perception and memory that

make it quite untenable. A first and major difficulty is that a single look at the world with the eye contains more information than the nervous system can record. All the details, imprinted momentarily on the retina, involve an immense amount of information, and most of it of quite a trivial nature. If the information involved in the infant's first view of the world were recorded in the infant's memory, then the entire storage capacity of the entire system would have been used up. Obviously this does not happen. Information is recorded selectively. Only a very small part of what the infant sees is ever recorded in the infant's memory, and the same is true of an adult. All of us see much, but record only a tiny fraction of that information. From the earliest days of infancy, each of us is highly selective in what is recorded in memory.

Selectivity in what is recorded in memory implies a special relationship between memory and perception. The human memory system appears to be so designed that it is selective in what it will record. Most of what the infant sees is not recorded, because the memory system is not equipped to record it at the time of exposure. The behavior of the infant shows that the visual perceptual-memory system of the infant is well equipped to record certain types of information. For example, the eyes of the infant, in the first few weeks of life, will follow a line or boundary from one end to the other. If there is an intersection of the line or boundary with another line or boundary, then the eyes of the infant will stop and fixate intently upon the intersection. The eyes of the infant seem to be programmed to study the boundaries of objects, and to record information about boundaries.

This tendency of the infant to study the boundaries of objects reflects a basic strategy of the perceptual-memory system for extracting data from the environment. The boundaries of objects are critical pieces of information, not only in the identification of the objects, but also in relating to those objects. The infant can grasp an object if the infant understands where the boundaries of the object are. The importance of the boundaries of objects is reflected in the fact that one can draw an excellent representation of virtually any object by using a pen to sketch the boundaries. Such line drawings are easily recognized, not only by humans, but by other primates, who easily recognize line drawings of common objects. The human information system seems to have a special propensity for picking up boundaries and lines.

Although modern psychologists have been reluctant to concede that the human information-processing system has any inherent capacities for processing information, much of what the infant does implies the existence of such a capacity. The attention to lines and their intersections is one example. Another more controversial one is the reaction to the human voice and the human face. Infants have been described as socially-precocious creatures. They attend to the human face from the earliest days after birth. One of the remarkable performances of very young infants, in the first few weeks of life, is that of imitating the protrusion of the tongue of the caretaker. This feat is remarkable in that the infant has never seen his own tongue, and can hardly have discovered that he has a tongue similar to that of his caretaker. This behavior implies that the infant has some inherent comprehension that the head of the caretaker has components similar to that of his own head, and that he can do with those components what the caretaker does with the caretaker's components. Oddly enough, the capacity to imitate this act disappears after the first few weeks and does not reappear for many months.

A more controversial area is that of speech comprehension. There is quite general agreement that the infant is well oriented towards human speech from birth, and works on cracking the code involved. Some speech experts go so far as to take the position that infants are born with a general system of grammar built into their nervous systems, which forms the basis for cracking the speech code of the language to which they are exposed. Authorities disagree upon the extent to which the infant is programmed with a set of rules which enable it to slowly decode the speech to which it is exposed. As a minimum, the infant has to have some understanding that speech has some kind of structure, if the structure can only be found. An infant thus internally programmed would search for structure, but the understanding of speech involved far more than a mere understanding of structure, for the infant has to search out the situations in which speech is used and must discover for what results it is employed. The innate social dispositions and understandings of the infant may quickly link speech to social activity. The point to note is that every aspect of the development of language understanding requires that there be something recorded in the nervous system, in memory if one likes to use the term, that is essential as a foundation for developing understanding.

Although it is not known precisely the kinds of programs for guiding perception that are stored in the memory of the infant, and particularly for guiding the perception of the visual world and the world of speech, great progress has been made in identifying these programs in recent years. Without these programs the meaningful exploration of the world could never begin, and they are the foundation upon which all later knowledge necessarily grows. As that knowledge grows there are ever-expanding horizons of what can be perceptually understood. The exploration of how knowledge begins in the human has involved the revival of the idea, developed by the philosopher Immanuel Kant, that the child is born with a fundamental capacity for organizing information about the fundamental properties of the environment. These properties are those of space, time, the permanency of objects, and causation. Kant referred to these as the categories of experience.

Much of the research today on the development of perception shows the obvious imprint of Kant's ideas. Although the work of Jean Piaget did much to revive the Kantian view of perception, Piaget himself has been rejecting of suggestions that any aspect of behavior has an innate basis, with perhaps the exception of reflexive behavior. Nevertheless, much modern research, and notably that of Bower and his associates at the University of Edinburgh, have supported the position that at least the category of space has an innate basis.

There is no question that the infant's perception of the world is not as William James suggested, a "blooming, buzzing confusion." The evidence suggests that the infant sees objects in a spatial context, though in a much more primitive way than does the adult. There is also evidence to suggest that the infant is born with a native concept of the unity of space, and that the space involved in vision is the same space as is involved in locating sounds in space. Furthermore, the infant's response to colors is very much like that of the adult in that the infant seems to categorize colors into the common categories of the adult world. The perception of the infant is far more sophisticatd than earlier workers thought it to be. The research workers of earlier decades did not realize how sophisticated the apparently naive infant actually is.

Thus the human seems to be born with a perceptual system that will interpret the environment in a particular way. The perceptual systems are not the highly flexible systems that they were thought to be a generation ago. The knowledge that can be gained from our environment is highly restricted to the knowledge that our perceptual systems permit us to have, and we are correspondingly limited in the knowledge we can acquire about our environment.

The views presented in previous paragraphs suggest that there is great uniformity in how individuals process information. Our information systems are built around a capability for developing knowledge about the fundamental properties of the environment that must be mastered if an adaptive relationship to that environment is to be developed.

The point has been made that the perceptual systems have associated with them analyzer mechanisms which must be compatible with the memory system. Components of the analyzer mechanism involved in perception, together with some aspects of memory, are functioning shortly after birth, but there are others that seem to require stimulation for them to develop normally. One basis for the latter statement is the research which has been undertaken on the lazy-eye phenomenon. If one of the eyes of the child does not function well, then it may gradually lose its utility. Now the interesting feature of the phenomenon is that the eye itself does not degenerate. What happens is that a component of the information-analyzer mechanism in the central nervous system fails to develop properly. The neural mechanisms related to vision require stimulation for full development. The eye that is not used does not provide the stimulation necessary for the development of the corresponding neural mechanisms. The treatment of the condition, when it is found in early childhood, is simple. All that has to be done is to cover up the good eye and to make the poor eye do the work. The phenomenon has been studied in the cat, which has a visual mechanism very similar to that of the human. An eye of a kitten can be closed at birth and then, later, when the kitten has become a mature cat, one can test the ability of the cat to use the eye. One can show that not only has the cat the ability to use the eye but that parts of the visual tract have failed to develop. Through such studies one can show that the lazy-eye phenomenon is not a result of eye deteroriation, but is a result of the failure of the neural-analyzer mechanism to develop.

The lazy-eye problem raises many interesting questions about how much stimulation of the nervous system is necessary for full development, and what kinds of stimulation are necessary. In a sense, the lazy eye is stimulated as much as the good eye in the untreated child, in that both eyes receive as much light and images are produced in each. Much more than simple stimulation is involved. For the lazy eye to develop properly, not only must there be images falling on the retina, but an effort must be made to use the information in some way. The phenomenon is not produced by an absence of images alone; the images have to be properly focussed, and perhaps may have to be used as sources of reactions, if they are to function in developing the visual analysis system.

THE PRIMACY OF VISION IN THE CONTROL OF HUMAN BEHAVIOR

There is mounting evidence that vision, in the case of the human, plays a role of special importance in the control of behavior. The strongest evidence for this comes from the study of babies who are born blind. These infants show an extraordinary inability to explore the environment. They will not reach out for objects that make sounds, and it is very difficult to stimulate these infants in such a way that they will undertake any kind of exploration of their environment. Although one is tempted to explain their behavior as a result of a fear of a world they cannot perceive, this does not seem to be the correct explanation. In the case of the infant with some vision, it appears to be vision itself that is the chief condition that makes the infant explore the world. Vision is the source of the stimuli that result in environmental exploration.

The dependency of the human upon vision for action is a feature shared by most higher animals derived from tree-climbing ancestors. A tree-climbing animal is dependent upon vision in a way that the animal tied to the ground is not. Most animals that live on the ground, and that have no capacity for climbing trees, have quite limited

vision. Thus the wolf has limited use of vision, and locates most of its prey by means of smell. Vision is of importance only to those animals that can see the world at a great distance, and the vision of the human permits a direct orientation to distant objects. In addition, the human is equipped with color vision, an important characteristic of arboreal creatures, in that it permits them to discriminate ripe from unripe fruit, also seen at a distance.

Many books on perception of 10 or more years ago took the position that touch was the dominant perceptual system of the infant, and that explorations of the world through touch came to educate the sense of vision. The evidence accumulated since then tends to show that the reverse occurs, and that vision is dominant over touch. Many experiments have been undertaken in which there is a discrepancy between what is experienced through touch, that is to say through the haptic system, and what is seen. In all such experiments, where there is a conflict in the data provided by the two perceptual systems, the visual information is likely to take over and guide action. The dominance of visual information is very striking in all the experiments that have been undertaken.

PICTORIAL VS. VERBAL MEMORY

There is also another line of evidence that suggests the particularly powerful role of the normal perception of natural objects in relation to the perception-memory process. When the same inforamtion is learned in a pictorial form and in the form of spoken or printed words, the pictorial form is remembered far more easily than the verbal form. The difference is very striking, but the basis for it is difficult to understand. This does not mean that the visual system imprints information on memory better than does the auditory system, for the difference does not appear when a comparison is made between the learning of words presented auditorially and the same words presented visually in a print form, though some individuals do learn better through the one modality rather than through the other. In order to begin to understand the difference between the pictorial task and the verbal task, one has to note that the picture of an object, such as a shoe, includes a wealth of detail that is not present in the printed or the spoken forms of the word "shoe." When the picture of a shoe is presented for a few seconds, the viewer may take in as much information as can be taken in during the brief exposure. During a five-second exposure a person may recognize that the object presented is a shoe, and even classify the shoe into a smaller set of shoes such as gym shoes, dress shoes, or running shoes. Much of the detail will still escape the viewer, but another five seconds of exposure will permit the absorption of still more information, and each additional exposure of five seconds will permit the assimilation of further information. The same is not true of the exposure to the printed or auditorially-presented word. When the word is presented auditorially for a second or third time, some additional information will be recorded, such as whether the voice was high or low pitched, and whether one syllable was emphasized rather than another, but the additional information is trivial and has nothing to do with the nature of the shoe. A picture permits the viewer to undertake an almost endless task of taking in more and more information, but the corresponding verbal task does not.

One can remake the verbal task in such a way that it is more like that of the pictorial task. The verbal task then becomes more than simply perceiving the repetition of a single word, and involves a phrase such as "A leather dress shoe." Just as a second presentation of the picture permits the taking in of more information, so the second presentation might read "The shoe has laces and a smooth leather upper." Further presentations could elaborate upon the details of the shoe and permit the reader to elaborate his idea of the particular shoe in much the same way as the viewer of a picture slowly elaborates his idea of what is in the picture. One wonders whether retention of the pictorial material would be different from that of the verbal material under these conditions.

CAPACITY OF THE INFORMATION SYSTEM

The environment provides enormous amounts of information, and all organisms are remarkably built so that they can extract from this morass of information that which is important for survival. The process of extracting the vital information begins at the sense organs, and ends at the highest level of the nervous system. One cannot speak easily on the information capacity of the total system in that the capacity is different at different levels. For example, the eye has an enormous capacity for handling information at the level of the retina, but the highest level of the nervous system that handles visual information has a very limited capacity for handling information. The different perceptual systems also have very different capacities for handling information. The primitive taste-smell system is a very low-capacity system. The auditory sensory mechanism has a higher capacity than does the smell-taste system, but its capacity is not as great as that of the visual system.

Information analysis begins at the sense-organ levels. The eye is clearly structured to provide an analysis of visual information in terms of color components. Through a physiological mechanism, known as lateral inhibition, the retina itself seems capable of emphasizing the boundaries of objects, at those points where there is maximum contrast of light and shadow. Some organisms undertake a quite complex analysis of visual information at the retina level. Thus the retina of the frog seems to be able to identify, at the retinal

level, small objects which have a particular form and motion. Whether the human retina can undertake such complex forms of information analysis at the retinal level is unknown. The methods used to study the retina of the frog cannot be used to study the retina of the human.

At each level of the nervous system some analysis of information is undertaken, and this analysis reduces the amount of information with which the next higher level of the nervous system has to cope. The result of this is that a certain kind of filtering takes place as information is transmitted from the sense organ level to the highest levels of the nervous system.

The information capacity of the highest levels of the nervous system is an indicator of how much can be attended to at any one time. The prevailing view is that the information capacity of each of the perceptual systems is the same. The capacity of the highest levels is still a matter for controversy. Some have argued, for example, that to comprehend a symphony requires an information capacity of about 100 bits per second. However, one should be hesitant in concluding that the information capacity of the information system of the auditory system, at the highest level, is about 100 bits per second, because listening to a symphony may not involve listening to every aspect of it every instant of the time. Indeed, the first time that one hears a particular symphony one may understand it only to a very limited degree. Even an experienced conductor will want to study the score of a new symphony he has never heard, before exposing himself to the music as it is played. After hearing a symphony many times, one may listen for particular features of it, knowing all the while that the rest of the symphony is there, even though one may not be hearing it at the time. Listening to a symphony, at a sophisticated level, may involve attention to first one aspect, and then to another aspect of it. In so far as attention is restricted, it does not call for the information capacity that a mathematician's calculations might indicate the act of listening to a symphony might require.

A distinction must be made between the information capacity of a system for handling a continuing flow of new information, and the information capacity of a system for handling information received during a particular presentation. The former would be estimated in bits per second and the latter in bits.

One cannot be very specific at this time in estimating the information capacity. One can say that the retina has a capacity for handling information in the millions, if not billions, of bits per second, and that the highest levels of the nervous system have corresponding capacities of less than 100 bits per second. A central educational problem is how to ensure the reduction in information in such a way that the relevant information reaches the highest levels. One suspects that, all too often, the trivial information is that which reaches the highest levels of the nervous system.

An important problem in the development of instructional materials is that of guiding the perceptual process in such a way that the highest levels of the nervous system select, from the mass of information presented, the small fraction of the information that is of crucial importance in the particular context. The task is like that of the prospector panning gold from a stream. From the handful of silt that is placed in the pan, only a small residue of gold will remain after the washing and panning process has been completed. There are many ways in which the designer of instructional materials can do this.

One obvious way is to present information in a form that contaminates it the least with irrelevant information. Line drawings and simple diagrams are attempts to do just that. Word descriptions can be pared down to essentials in order to facilitate communication. Sometimes an actual experiment with physical materials can demonstrate a phenomenon under simplified circumstances. For example, one can actually show with rods of real materials how heat produces expansion. In such a demonstration, there is no doubt in the learner's mind about the relevant features of the demonstration which must be attended to. Before field trips are taken, the teacher can orient the pupils on precisely the conditions that should be attended to and observed. If the latter is not done, the pupils will return from the field trip with miscellaneous information, much of it of a trivial character.

Every teacher has the experience of showing a film and at being surprised that the children did not grasp the main points that the film was designed to bring out. The problem is that the film typically presents millions of bits of information, from which each member of the class extracts some small amount of what that individual conceives to be the relevant information for retention. All too often the teacher simply does not understand how children, all of whom see the same film, can possibly learn such a diversity of facts, many of which are wholly irrelevant to the idea that the film was designed to present. This difficulty can be prevented through orienting the pupils, prior to the showing of the motion picture, concerning the relevant pieces of information to look for. This orienting process provides decisions for the information-selection processes of the pupil. Without such direction, the pupil may do more than take random samples of information from the motion picture. Each pupil may obtain a different random sample. Indeed, there is much evidence that perception often involves taking a random sample of information, and, in the 1960s considerable research was devoted to perception as a sampling process.

FILTERING AND PIGEONHOLING AS ORDERLY INFORMATION REDUCTION MECHANISMS

The most widely-held theory concerning the

way in which information is reduced by the nervous system has been a theory developed by Broadbent, known as filter theory. Recently, Broadbent has added to filtering a second process which he calls pigeonholing.

The essence of filter theory is that the nervous system can be set so that only certain information will pass to the higher centers. The idea of information selection and reduction through filtering fits nicely with common experience. If one is looking for mushrooms in the woods, then any mushroom-like object will seem to catch our attention, but if we are not looking for mushrooms then one may not see any, even if they are there. Filter theory suggests that one may set the visual perceptual system to see mushrooms, or to see any other class of objects. The analogy is with a mechanical filter, but there is nothing known about the perceptual systems to suggest how a filter system might work in relation to perception.

There are some common human tasks that involve little more than filtering. Scanning the pages of a book in search of information about a specific topic, such as conditioned reflexes, involves adopting a set to see the term **conditioned reflex,** whenever the term appears. This is like setting a filter that will screen out every word except the pair of words for which one is searching. Everyone who uses books knows that kind of task can be performed with surprising efficiency. The words that one is looking for seem to jump out of the page, though occasionally one may miss a particular item. An interesting feature of this kind of task is that one can set the filter for a number of different items, all of which are searched for at the same time. The evidence indicates that one can search for ten items simultaneously with the same efficiency for each item as one can search for a single item. There is also a commercial version of this task found in the work of those who scan newspapers for newspaper-cutting agencies. Those who search the newspapers may scan for as many as 100 items at the same time. They can do this because they have worked long at the task and do not have to memorize each day a new list of 100 items. The list of searched-for items has been slowly built up during a long period of work. Filter theory accounts rather adequately for these forms of behavior, as well as for many others.

Filter theory has its critics. One criticism is that in order to see the apples on the tree, for which the filter is set, one would have to examine each leaf to determine that it is not an apple. Such a criticism is not entirely sound. There are mechanical filters that will sort out a particular class of objects without examining each and every object. A mechanical separator, at a gravel pit, sorts out pebbles of different sizes without examining each pebble to determine the class to which it belongs. The modern airport security system sorts out heavy metal objects without examining every object. The metal objects trigger an alarm, but the system ignores the other objects.

Filter theory is related to the theory of attribute analysis, in that the theory implies that the filter is set in terms of the attributes of the objects that are to pass the filter. Thus, in looking for mushrooms one is set to respond to small white objects. Smallness and whiteness are critical features which enable one to identify mushrooms. With the filter thus set, objects that do not have these critical features will be excluded. A large sheet of newspaper will not be approached. The filter also represents a coarse screening. One is not sure that all relevant objects that are spotted will be mushrooms. Those objects that pass the filter will be inspected further. When the person searching for mushrooms sees a small white object, the object will be checked for correct shape and for correct detailed appearance. The filtering out of a class of objects represents one stage in a sequence of stages used in the location and identification of the objects.

The orientation of pupils who are to see some audiovisual materials can be thought of as partially a matter of setting the filter to pass certain classes of information, but the orientation involves far more than this. Orientation also involves alerting components of the memory system to assimilate certain pieces of information in particular ways. Before showing a film on reptile life, a single sentence on the part of the teacher may set the filters of the pupils so as to result in selective attention to reptiles, but the more difficult task of the teacher is to explain to the pupils that they are to try and comprehend how the physical form of each reptile gives it a capacity to survive in its environment. In other words, the pupils must have some understanding of how they are to assimilate selected aspects of the information.

Pigeonholing is an entirely different form of information selection, which differs from filtering in important ways. An example of pigeonholing is found in looking for books that might contain information on a particular topic, but whose titles provide no direct cues as to whether the topic is covered in the book. If one is looking only for books that have titles which refer to a particular topic, as when one is looking for books on, say, masonary, one only has to set the filter to pick up the titles that contain the work. A simple setting of the filter will enable us to locate the books. However, if one were looking for information on different kinds of bricks, one probably would not get very far by examining only books with the word **brick** in the title. One might have to wade through books with many different titles to locate the information needed. One would probably look at books on masonry, but also books on ceramic materials, on clays and earths, on building materials, on the chemistry of ceramics, and on many other topics. In looking for the needed information one would have to make some judgments as to whether each book should be looked at further, or whether the title should eliminate it from further consideration. This is the process of

pigeonholing. It requires thought and knowledge. It does not have the rapidity of filtering, and neither does it have the automaticity of filtering. It is a thoughtful and slow process. Pigeonholing shares with filtering the objective of reducing large amounts of information to manageable quantities.

OVERLOADING THE SYSTEM

All information systems respond in some way to overload. A telephone system, when subjected to overload, handles some calls and gives a busy signal to others. The human system has several ways of handling overload. When the human is under pressure to take in more information than the system can handle, the common response is for there to be a total breakdown in the reception and use of information. This kind of response is sometimes seen in psychological experiments. Ask a subject to learn a series of 10 nonsense syllables flashed onto a screen at the rate of 2 or 3 a second, and many adults will, after 10 trials, have learned none of the syllables. One might expect them to be able to learn at least the first or the last syllables in the series, for these can be easily read, but that is not what happens. The learners who fail to learn a single syllable are overwhelmed by the speed at which the syllables are flashed onto the screen. They make no effort to organize their behavior so as to be able to pick up a few of the syllables and to ignore the rest. Their behavior is directed towards mastering the task as a whole, and that they cannot do.

Trained individuals may take a very different approach to situations that involve information overload. A person who works in a busy office may learn to process the information only from those aspects of the job that have to be processed immediately. The worker may not at times answer the phone at his desk, even though he knows that the call is for him. He may not respond when he is called by name by another worker. Such a worker is handling the overload in much the same way as the telephone system handles overload, by making a decision as to what information is to be handled and ignoring the rest. However, the point should be noted that this strategy for handling overload requires prolonged training. It is not the typical strategy of the child, who is much more likely to respond to overload with a response of bewilderment.

Overload is observed in classrooms in which the teacher talks rapidly and expansively, and without attending to the responses of the pupils. A bewildered class results. Programmed texts control the rate at which information is provided to some degree, though much of the control remains within the decisions of the learner. One suspects that information should be processed by the learner at a rate just below that which produces overload, but that rate has to be largely a matter of the judgment of the instructor. The learner may not necessarily choose that optimum rate if left to set the pace. Some learners will even overload themselves, as when a person sets goals for reading textbook materials that are far beyond those that can actually be achieved.

Problems of overload virtually have not been studied as they should have been, and neither have there been investigations of how individuals can be trained to cope with situations involving potential overload. There is a little evidence from experimental studies showing that individuals typically fail to cope with information overload in experimental situations, but much more systematic research needs to be undertaken.

The setting of the filter is one way in which potential overload is handled. Indeed, overload is most likely to take place when there is virtually no specific filter setting.

ORGANIZATION IN MEMORY AND PERCEPTION

In previous pages some stress has been placed upon the idea that some information has to be stored in memory before meaningful perception can take place. Many lines of evidence point in that direction. The organizations of information in memory that make perception possible can be viewed in several different ways. There are obviously innate stores of information that make initial perception possible, and around which new information becomes assimilated. There are also later-developed organizations which, necessarily, have to be linked to the inside organizing elements.

Basic organizations in memory that result in the acquisition and utilization of information, in the form of some kind of action, are commonly viewed as what are called **schemata** in current literature. The term was first used in a psychological context early in the century by a neurologist, Henry Head. In recent times the term has been extensively used by Jean Piaget, also to describe organizations of behavior around which learning takes place.

Schema theory takes the position that all learning takes place in relation to schemata that grow in scope as learning develops. The theory is not particularly clear about how information is added to a schema, but the theory implies that the acquisition of information can take place only in relation to a schema. In the absence of a relevant schema, learning can not take place. This view of learning has come from traditional epistemology. John Dewey, for example, refers, in many of his works, to the "assimilation" of knowledge, implying that knowledge is built, and can be built, only in relation to existing knowledge structures. One cannot learn that for which there is no structure to which it can be assimilated. Piaget has embraced assimilation theory, and has taken the position that the growth of knowledge, through the perceptual systems, can take place only in so far as there are schemata to which the new knowledge can be assimilated. Piaget also extends that theory by introducing a second way in which knowledge is acquired, and that is through the process of

accommodation. The latter involves an adaptive change in the schema itself, in contrast with assimilation, which involves only adding to the scope of the schema.

The theory is correct in asserting that the acquisition of knowledge always requires some pre-existing internal structure to which it can become assimilated. Other aspects of the theory remain controversial, even among whose who embrace the theory. Piaget, for example, emphasizes the action components of schemata, and sometimes even asserts that **knowledge is action**, much as behaviorists have asserted. Other psychologists working in the field of perception find evidence that mere exposure to information may result in the information becoming structured, organized, and retained. The classic studies of Fantz showed that merely exposing an infant to simple designs resulted in the retention of some information about those designs. Eleanor Gibson describes an experiment showing how exposing adults to designs results in greater discriminability of those designs. In such experiments, the action component of the schemata involved is quite minimal. Both the infant and the adult move their eyes while scanning designs, but this is a part of the information acquisition process, rather than a response to the information acquired.

In Piaget's later writings, he makes a distinction between the earlier organizations of behavior, which he refers to as schemes, and the later, largely learned, organizations and organizers, which he refers to as schemata. These later organizations, which have inputs, outputs, and central components, he also refers to as structures. In the mature intellect, major organizing structures are related to logical thought. One can identify logical inconsistencies in what one reads or hears because the inputs will not assimilate to the logical structures that one has. When the adolescent hears the adminsitrator of an intelligence test tell him that, since those killed in railway accidents are generally in the last car of the train, and that as a safety measure the last car should always be disconnected from the train before it starts, the adolescent will recognize that the logic is faulty, because there is always a last car. The 7-year-old will see no logical inconsistency in the statement, because the child has not yet acquired the logical structure that permits the analysis of the problem.

All instructional materials are useful only in so far as there are schemes or schemata to which the content can be assimilated. There are children still in our society, who come from very impoverished homes, who have virtually never seen anybody read until they come to school. For such children books are quite meaningless objects, for they have nothing to which they can assimilate the idea of a book. Such children will face the task of learning to read with complete bewilderment, for they have not yet learned what reading is or what it can achieve. The investigations at the University of Chicago, in the early part of the century, showed clearly that the home experiences of children related to reading were crucial components of the task of learning to read. These home experiences presumably develop schemes or schema related to reading. Even though the child may not be able to read, the schemes or schema enable him to recognize the significance and the nature of the reading task. The experiences develop schema to which the tasks related to reading, provided by the school, can be assimilated. Structures that permit the interpretation of experience have to be built in an orderly way if they are to function effectively.

The discussion of schemata raises the long-discussed issue in education of the role of verbal responses versus direct-action responses in the building of knowledge. Piaget has written extensively on this issue over the years. He minimizes the effect of mere exposure to verbal information in that the development of a schema always requires the development of the ability to use inputs in a way that constructs outputs. Although some evidence has been cited that inputs alone may sometimes impress themselves on memory and become a part of permanent knowledge, learning can be enormously enriched if they are accompanied by outputs. Consider an 8-month-old infant who has been presented with a small red wooden cube. If the infant can only see the cube behind a sheet of glass, the amount of information the infant can acquire is extremely limited. If the infant is allowed to manipulate the cube, then the situation permits him to turn the cube in different directions and to begin to comprehend the 3-dimensional nature of the object. The infant can also explore the solid properties of the object and learn that a sound can be made by banging the cube on the table top, but that no sound is produced when the cube is transferred from one hand to the other. The infant will also be able to feel the edges of the cube and relate what is felt to what is seen. When the infant is allowed to handle and manipulate the cube, a wealth of information can be obtained that could not otherwise be obtained. Manipulation and action can enrich schemata in a way that passive observation cannot. In turn, knowledge becomes linked to action. Action is not only a rich source of knowledge, but it builds action-related knowledge. The traditional view of education has been that the same is not true of older children. Let us consider the case of an adolescent in a general science class.

Suppose that a general science class is discussing the way in which positive lenses form real images. The expository method of teaching would involve a description of a positive lens, and the way in which it formed an image, and perhaps a demonstration of image formation. A much greater range of information could be meaningfully explored if the student were given opportunities to experiment with image formation. They would then learn the degree to which the distance of the lens and of the screen could be varied and still

produce an image that appeared to be in focus. The children could explore the effect of tilting the lens slightly and what happens when half the lens is covered, and other interesting effects. The adolescent can ask important questions about image formation and then find answers experimentally. This is good training in how one should go about exploring the world, and it is fun. Direct experimentation with lenses provides a richer source of information than can be easily provided through teacher-conducted demonstrations, and thought and action become closely linked as they must be if they are to be effective. Also, learning to ask significant questions is at least as important as finding the answers. In addition, there is some evidence that undertaking action oneself seems to impress the results on memory better than when one merely observes another asking the questions and finding the answers.

Despite all evidence to the contrary, there are those who still believe that knowledge can be efficiently poured into the student, in a manner analogous to the filling of a jar with water. One of the most expensive educational development projects of the last quarter-century involved the development of films covering every phase of elementary physics. Hundreds of films were made at a cost equivalent today of perhaps 30 million dollars. The idea behind the film was that knowledge could be poured into the student. Fortunately, the physics teachers of the country had the good sense not to use the materials, which have remained unused for more than a quarter century. One has to admit that the materials are superbly made, and beautifully staged, but they are just not designed in terms of how pupils can learn physics effectively. There is a place for the expository teaching of physics, but probably not until after the students have had some opportunity to explore phenomena for themselves.

An important developmental factor that determines whether the individual can or cannot profit from expository teaching is the extent to which activity can be internalized. The mature thinker can conduct experiments in thought. Every scientist does this, imagining what would happen if certain conditions existed. The mature thinker has great capability in manipulating internal representations of the external world, but the immature thinker often cannot. Studies of the internal representation of children in the preschool years indicates that they can represent internally that which they have seen, but cannot represent the same situation with certain features changed. Such children cannot manipulate internal representations of the world, and, hence, are very limited in what they can conceptualize. For such children, much learning has to take place through the physical manipulation of the concrete world, and it is through such manipulation that knowledge is built.

Even after some capacity to manipulate internal representations has been achieved, the ability to do this remains limited through the elementary school years, during which time the capacity to represent abstract ideas remains extremely limited.

TRANSFER ACROSS PERCEPTUAL SYSTEMS

The prevailing view, until recently, was that the infant was born with completely independent perceptual systems for acquiring information. The infant's concept of space as related to learning was believed to be completely independent of the infant's concept of space as related to vision, and the haptic system provided a further independent concept of space. The unified concept of space of the adult was believed to be acquired through learning, and slowly points of space in one of the systems came to correspond with points of space in one of the other systems. This view has, today, been largely abandoned. The prevailing view is that the infant is brought into the world with a unified concept of space.

The new view, incorporating the unified concept of space in the infant, is not really a surprising conclusion. Most higher animals are born with a completely unified concept of space. Thus the newborn calf or foal will raise itself on its legs immediately after birth and move towards its mother. In order for the calf or foal to be able to stand up, the calf must be able to coordinate space as experienced visually with space as experienced through the muscles of the legs and the haptic system. The calf also seems to be able to locate objects in space almost immediately, including the nipples through which it is fed. The human may have somewhat less capacity for comprehending space at birth, and much less capacity for demonstrating the understanding that the calf has, but the cumulative evidence indicates that the infant has far more understanding of a unified space than earlier generations gave the infant credit for having.

The implication is that the perceptual systems, at the higher levels of information processing, are unified to a high degree. What is learned auditorially about events in space is assimilated into the same representation of space as that into which visual information is incorporated. There seems to be a single, unified, internal representation of space and the spatial properties of objects. This fits well our common concept of our understanding of space. A surgeon who probes into the body through a small incision understands what the probe tells him of what is there. When the incision is enlarged he is not surprised at what he sees, for he sees just about what the probing tells him was there. What he sees is completely coordinated with what he learned through the haptic system. A person does not, of course, have an auditory system that provides very precise information about spatial properties, though there are other animals, such as the bat, that can explore space with precision through the auditory system.

A large amount of evidence has been collected to show that information learned through

one of the perceptual systems become rapidly available to the other systems that can handle similar information. This has been called the sensory-integration hypothesis. There is some evidence that sensory integration improves during childhood, and also that brain-damaged children may not show the same degree of sensory integration. One important implication of the sensory-integration hypothesis is that the same information may be learned through one or another of the perceptual systems, though not all information can be learned through all systems. For example, color cannot be learned through the auditory system. At one time psychologists suggested that verbal mediators undertook the transfer of information from one perceptual modality to another, but the evidence does not support that position. A more tenable position is that the information from all perceptual modalities enters a common memory system. Others have taken the position that in normal individuals, all information tends to be translated into a visual memory system. Regardless of the mechanism, the information does become readily translated from one system to another, and there is extensive transfer across the different systems.

RECEIVING INFORMATION THROUGH MORE THAN ONE PERCEPTUAL SYSTEM

Instructional devices that provided inputs through both eye and ear began to gain a market in the late 1930s and received enormous impetus to their development during World War II, during which time they became a major means of instruction in the military. The talking motion picture, as it was then called, came to be viewed as a major educational device, and the publishers of educational materials enthusiastically became major sponsors of this new enterprise. Around the enterprise there grew up a theory of information transmission which, to some degree, justified its development.

The central postulate of the theory of audiovisual information was that more information could be acquired if information was pumped in through two perceptual systems than if the information was transmitted through only one. This aspect of the theory seemed to imply that the limitation upon the amount of information which could be assimilated resided at the sense-organ level, when the actual limitation is at higher levels of recognition and analysis. The general theory of audiovisual instruction provides an umbrella coverage of a number of different conditions, each of which should have been investigated separately. The condition that the writers of books on audiovisual materials usually had in mind was the one in which the same information was transmitted, simultaneously, through the auditory and visual systems. A simple case of this occurs when the instructor reads aloud to the pupil material that the pupil reads simultaneously to himself. A more complex case, in which there is a less-close parallel between the auditory and visual inputs, is that in which the student examines a visual display while a voice describes the display. These were the main conditions that the audiovisual theory discussed, and these involved redundant information transmitted through two different perceptual systems. More complex situations involve the transmission of non-redundant information through two perceptual systems, as when an object is shown through the visual channel, and the name of the object is given auditorially. The association is learned across the perceptual channels. An additional condition is that in which the auditory perceptual system is used to direct the activity of the visual perceptual system, as when a voice tells a viewer to look at a structure in the middle of the screen and to note certain features.

Early research undertaken both by psychologists and by educational research workers led to the conclusion that more was learned when information was presented through more than one perceptual system than when the information came in through a single system. However, the conclusion that information introduced through more than one system produced more learning, because there were two channels of entry, was a false conclusion. The apparent enhancement of learning resulting from the use of more than one perceptual system was a result of the fact that the learner could choose to learn through the channel that was the most efficient for that particular learner. Thus when all learners were learning through the most efficient channel for each, the resulting average performance was better for the group provided with both auditory and visual systems than it would be if there were no choice of systems. The individuals in the experiments almost certainly did not learn through both the auditory and the visual system at the same time, but learned through a single perceptual system chosen by them.

The situations which were explored in these early studies of multi-channel communication and learning used materials that were far different from typical educational materials. Some studies used nonsense syllables and single words. Others used prose passages, and one whole series involving the three perceptual systems of touch, hearing, and vision used patterns of left and right positions. These tasks are very different from those typically found in audiovisual instruction in which essential, non-redundant information arrives through both the visual and the auditory channel. Far more work needs to be undertaken to explore the latter condition of learning.

The research undertaken in the mid-1960s on this problem was dominated by the theory that information could be received only through a single channel at any particular moment. The term **channel** here refers to any coherent sequence of messages that have some unity to them. A perceptual system, such as the auditory system, might be bombarded by several channels of communication at one time, as when one is in a room and many people are talking at the same time, but

information is derived from only one channel at any particular time. If a person is talking very slowly, or saying very little, then a listener may not have to listen all the time to that channel to keep track of what is being said. Under the latter condition the listener may appear to be attending to two channels at once, but, in fact, there is a back-and-forth switching. The single-channel hypothesis describes rather well how individuals handle information. The highest levels of information-handling seem to operate very much like a single-channel system.

The single channel hypothesis implies that nothing is to be gained by transmitting simultaneous redundant information through two perceptual systems, though the use of two systems may permit the individual to select the perceptual system that is most efficient for the purpose.

During the last 15 years there has been a considerable volume of research on bi-sensory inputs of information. Much of this research has had to do with the rate of reaction to a stimulus presented through two perceptual systems versus through one. The results have typically shown a small increase in speed of reaction when two redundant inputs are used in comparison with one. A similar kind of facilitation is found on signal-detection tasks. A faint signal, transmitted through both the eye and the ear, is more likely to be detected than is a faint signal transmitted through either sensory channel alone. Such studies do not have any great relevance to education. Of rather greater significance are studies which show that signals transmitted through one perceptual system may have arousal effects which facilitate the reception of information through another perceptual system. The latter phenomenon bears a superficial resemblance to the technique used in instructional films in which the first few seconds of the film involve the playing of loud music, which may well produce an arousal effect. The laboratory experiments are sufficiently remote from actual teaching situations that studies need to be conducted with materials similar to those used in instruction, to see whether similar results are obtained with classroom materials.

There may be other advantages to methods of instruction that use more than one perceptual system at the same time. One system may be used to set the filter on the other system, as when the viewer of a film is told verbally to look for certain features in the visual display. Furthermore, the importance of imagery in promoting verbal learning suggests that verbal learning may be promoted, in some instances, through providing simultaneous visual material. Those who have developed materials for foreign language learning have typically used visual materials to build associations between objects and names of objects. These problems have scarcely been investigated in relation to the development of instructional materials, but they need to be systematically studied. There is a sufficient body of theory available at this time to guide a quite large and orderly investigation of the use of multiple perceptual systems in instruction.

SIMULTANEOUS VS. SEQUENTIAL INFORMATION PROCESSING

The perceptual systems, by their very nature, vary in the degree to which they are structured in such a way that they can take in multiple sources of information simultaneously. The ear is so structured that it has quite a limited capacity to do this. The cochlear in the ear can register several notes at the same time, and a chord is heard from which the trained musician can abstract the component notes. Most of the information coming in through the ear appears to enter the auditory perceptual system on a sequential basis, though complex speech sounds may involve simultaneous inputs, but that does not mean that the sequentially-ordered items of information are handled sequentially at the higher levels of information processing. A sentence cannot be understood by merely registering a sequence of words and assigning a meaning to each word as it arrives, one at a time. A sentence can be understood only in so far as the words that compose the sentence are all held in a memory system long enough for the structure of the sentence as a whole to be analyzed. A sentence could not be analyzed, to the point where meaning could be abstracted, if each word were somehow analyzed as it entered the system and only as it entered the system. Word position in a sentence is an important basis for assigning meaning in the English language, and a sentence has to be held in a short-term memory in order for analysis to be performed. Thus, the auditory system involves both sequential components of information-handling and simultaneous components. The input of speech may be largely successive, but the analysis at higher levels involves the simultaneous analysis of batches of information that have entered the system sequentially.

When language is transmitted through the visual system by means of print, the initial transmission of information is not of the sequential nature that it appears to be. Experimental evidence indicates that, at each fixation, a chunk of information is typically entered, each chunk consisting of several words. However, the chunk taken in through the eye is too small a quantity for analysis to be undertaken effectively at the higher centers, so chunks have to be held in a short-term memory until a large enough quantity of information is held to permit analysis. Some kind of holding mechanism obviously has to exist, even though the capacity of the eye is large enough to permit it to take in large amounts of information simultaneously.

An interesting question is whether or not the holding mechanism discussed with reference to the ear is the same as the holding mechanism discussed with reference to the eye. The issue has long been a controversial one, and the controversy has not

been settled. The problem is complicated by the fact that visually-transmitted work-sequences may be immediately translated into an auditory form, as when one speaks the words as one reads them. Some have suggested that all verbal material is coded into an auditory-verbal memory.

THE NEED FOR EXPANDING THE SCIENTIFIC BASIS OF EDUCATIONAL TECHNOLOGY

Most of the world's technologies existed, in a primitive form, long before they came to rely upon a scientific foundation. Iron has been smelted from ore for at least 2,500 years, but only in the last century did it become possible to control the smelting process with precision so that ingots that met precise specifications could be consistently produced. The quite large iron-smelting plants of the Roman era produced iron of variable quality, some of which occasionally approximated modern steel, but most of which was soft and malleable. Nevertheless, an iron smelting technology existed long before there was any scientific knowledge which could be used to guide the enterprise. The development of scientific knowledge not only permitted smelters to produce ingots to meet precise specifications, but also permitted great improvements in the properties of the metals that were produced. The primitive state of metal-smelting technology until the nineteenth century is comparable to the primitive state of educational technology today. Educational products derived from that technology are useable, but rather uncertain in just what properties they will have. A scientific knowledge of information processing and information storage seems to represent an important scientific foundation for the development of a vastly improved educational technology, though other sources of scientific knowledge will also play a role.

An odd feature of educational technology is its apparent detachment from the little scientific knowledge that is available, a detachment that perhaps reflects the limited scientific knowledge that has relevance for the field. Present policies of sponsored research place more emphasis upon conducting investigations within educational technology itself rather than in expanding scientific knowledge related to educational technology. Thus the N.I.E. is much more likely to fund research related to comparing three different forms of educational materials than research related to how knowledge is assimilated, or how it is integrated with other knowledge, or whether it makes a difference whether one perceptual system or another is used to take in the information. Even with the natural sciences, human information-processing is not a well-funded area.

Educational technology is also separated from scientific knowledge that might have relevance for its development by another significant fact. That fact is that colleges of education, which train most of those who enter the field of educational technology, do not provide any training in the behavioral sciences. Training in research for the educational technologist is largely limited to courses in statistics. There was a time, half a century ago, when at least some colleges of education recognized that training in the behavioral sciences had to be provided for those entering educational research, and there were even some colleges of education that housed the department of psychology. Today there is typically a complete separation of the behavioral sciences from whatever is taught in colleges of education. The result is a technology of education that derives nothing from a scientific foundation. Much of modern educational technology has no more scientific foundation than had the Roman metal-smelting plants. History shows clearly that a technology can slowly advance without a scientific foundation, but that its progress is extremely slow. The progress in metal production from Roman times to 1800 was minuscule, compared with progress since 1800. One can expect the same minuscule progress in educational technology, if it remains isolated from the main body of the behavioral sciences, as it is isolated today.

There are some signs that the isolation of educational technology is coming to an end. For example, there is at least one distinguished college of education that is developing a curriculum in neurophysiology, for those in education who wish to explore the implications of this important body of knowledge. A few isolated colleges and schools of education provide modern courses in perception and learning, sometimes even working with the department of psychology. Sociologists are now showing a return to their interest in education which they manifested earlier in the century. The interest in educational problems shown by some scientists in related behavioral sciences is not enough to produce a scientifically-based educational technology. The educational technologist must become thoroughly familiar with knowledge in related scientific areas, just as the metallurgist has to have a thorough grounding in chemistry and physics if s/he is to have success in improving the technology of metal production.

SOURCES AND REFERENCES

The purpose of this section is to indicate the sources from which the chapter was derived and also to provide a list of materials that a reader might turn to for the purpose of expanding her or his knowledge of the field. Fortunately, eminent scientists have devoted time to the development of a literature on the subject within the scope of the general reader. Such works represent stepping stones to the more technical literature in the field.

Current literature on perception, as well as the present preceding chapter, find their roots in J.J. Gibson's The Senses Considered as Perceptual Systems (Boston: Houghton Mifflin, 1966). The Gibson book was the first to view perception as involving information-gathering systems. The material on perceptual learning and the organizing

functions of perception are based, to a considerable extent, upon E.J. Gibson's work, Principles of Perceptual Learning and Development (New York: Appleton-Century-Crofts, 1969). Several well-written books, by eminent scientists, on the psychology of vision have appeared in recent years, and the books provide greatly expanded versions of the material covered in this chapter. One of the first of these outstanding books on visual information processing is that by R.L. Gregory, The Intelligent Eye (London, England: Weidenfeld and Nicholson), and another, more recent one is J.P. Frisby's Seeing (Oxford, England: Oxford University Press, 1980). Much of what is known concerning the way in which the brain processes information, and particularly visual information, has been summarized by the eminent physiologist, Cain Blakemore, in the thoroughly readable book Mechanics of the Mind (Cambridge, England: Cambridge University Press, 1977). The latter book is based upon a series of lectures given over the B.B.C. The September 1979 issue of the Scientific American is entitled The Brain, and provides a valuable review of much that is known about neurophysiology and the analysis of sensory information. Information analysis in the nervous system is discussed at a more technical level in a volume edited by R.F. Schmidt entitled Sensory Physiology (New York: Sprinter-Verlag, 1978). Since much of the work of the neurological analysis of visual information has been undertaken on the cat, the matter of the comparability of the cat's visual system and the human's is important. This is fully discussed in an article by R. Blake, "The Visual System of the Cat," (Perception and Psychophysics, 1979, 26, 423-448). Blake's article also reviews the evidence concerning the nature of the lazy-eye phenomenon and the establishment of the fact that the phenomenon is due to a failure of development within the central nervous system.

Attribute analysis is extensively explored in the 10-volume series, edited by E.C. Carterette and M.P. Friedman, collectively entitled Handbook of Perception (New York: Academic Press, 1973-1978). In this series, information analysis in each perceptual system is considered separately in volumes assigned to each.

Issues related to multimodal perception, that is to say, perception through more than one perceptual system, have been discussed in a very scattered literature. One aspect of this area is discussed by L.W. Marks in a chapter entitled "Multimodal Perception" in Volume 8 of the Handbook of Perception. This latter article largely ignores the kinds of problems in which the designers of audiovisual materials have been mainly interested in the past, namely, the transmission of redundant information through two perceptual systems. One source of information related to this problem is found in Travers' report entitled Research and Theory Related to Audiovisual Information Transmission (U.S. Department of Health Education and Welfare Contract No. 3-20-003, 1967).

The single-channel concept of human information reception was first developed by D.E. Broadbent, and is described in his book Perception and Communication (New York: Pergamon Press, 1958). A later version of filter theory is found in his article "The Hidden Preattentive Process" (American Psychologist, 1977, 32, 109-118)).

The concept of a schema has been extensively used in psychological literature throughout the present century, particularly by those psychologists who have broken away from an associationistic representation of knowledge. Piaget used the concept in his writings for over 50 years, but the concept is used by such moderns as U. Neisser (see his book Cognition and Reality (San Francisco: Freeman, 1976)).

The control of behavior by vision, apparent through the study of blind infants, is brought out in the work of Selma Fraiberg in her book Insights from the Blind: Comparative Studies of Blind and Sighted Infants (New York: Basic Books, 1977).

J.M. Kennedy's book A Psychology of Picture Perception (San Francisco: Jossey Bass, 1974), remains a valuable source of information on picture perception for those designing educational materials.